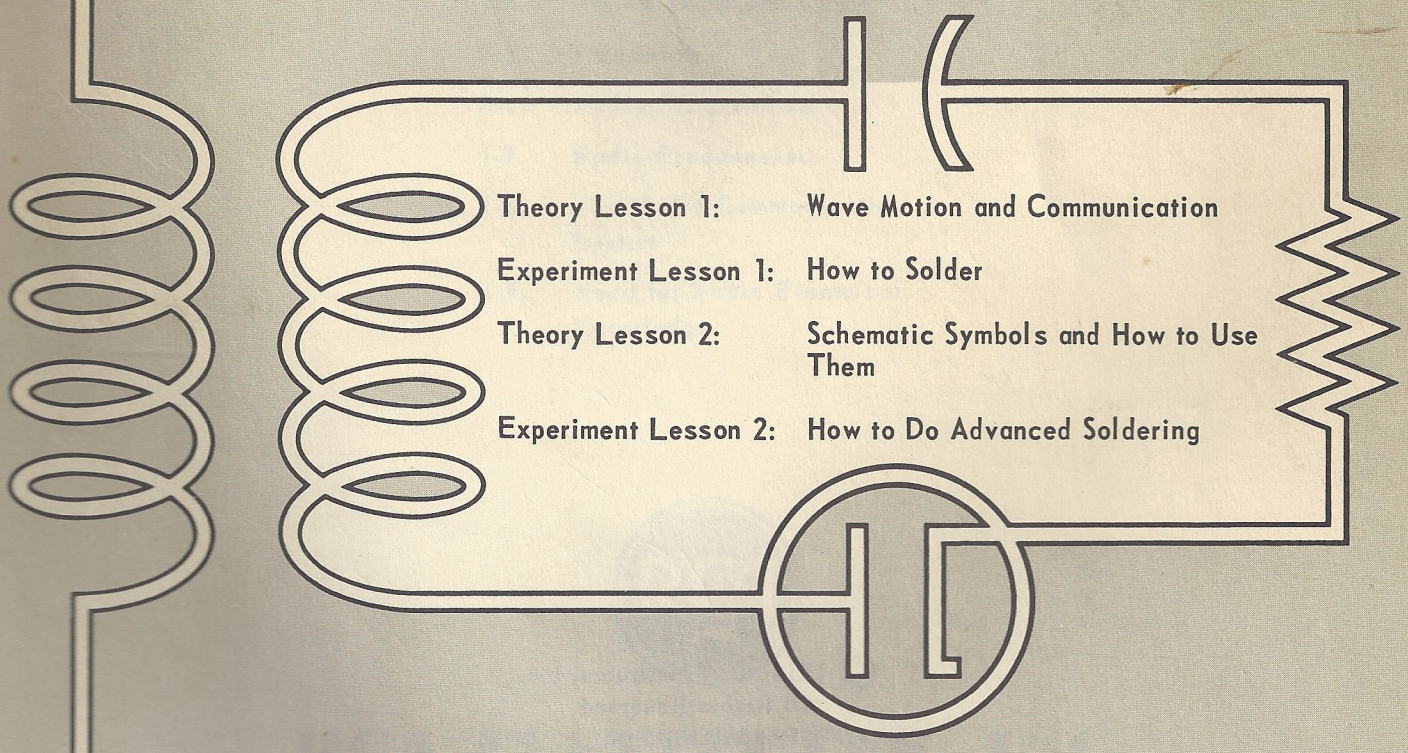
Study Group 1

ELECTRONIC FUNDAMENTALS



Theory Lesson 1:	Wave Motion and Communication
Experiment Lesson 1:	How to Solder
Theory Lesson 2:	Schematic Symbols and How to Use Them
Experiment Lesson 2:	How to Do Advanced Soldering

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York, N. Y.

ELECTRONIC FUNDAMENTALS

THEORY LESSON 1

WAVE MOTION AND COMMUNICATION

1-1. Sound

1-2. Wave Motion

1-3. Sound Waves

1-4. Wave Length and Cycle

1-5. Frequency

1-6. Audio Frequencies

1-7. Radio Frequencies

1-8. The Radio Communication System

1-9. Need for Basic Electrical Knowledge

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Theory Lesson 1

INTRODUCTION

Communication is the term for sending information from one person to another. There are two basic methods of communication: the visible method and the audible method. The visible methods requires the use of our eyes to receive information, as in the case of signaling with lights, flags, or smoke, waving our arms, or reading the words on this page. The audible method of communication is being used when our ears receive the information being communicated by shouting, speaking, ringing a bell, beating a drum, or blowing a horn. In other words, we are communicating audibly when we use sound to carry our meaning to one another. We are going to study audible communication in this lesson.

1-1. SOUND

Anything that can be heard is *sound*. You may be reading this in a quiet room. If so, stop a moment and listen. The chances are that you'll hear sounds that you were not conscious of when your mind was occupied with reading. Unless you visit a completely sound-proof room someday, you'll spend an entire lifetime surrounded by sounds.

1-2. WAVE MOTION

Just what happens when a sound is produced? Actually, sound is a form of *wave motion*. You are familiar with the wave motion caused by dropping a stone into a still pond or lake. Seen from above, as from a bridge or boat, the waves look like the illustration in Fig. 1-1. Seen from the water level, they look more like Fig. 1-2. Part *a* of the figure shows a stone dropping toward the water. Part *b* shows the stone pushing aside the water in its path. This brings the water level up around the stone and starts the first wave circling out from the stone. In part *c*, the stone has sunk below the water level, and waves are traveling out along the surface of the water.

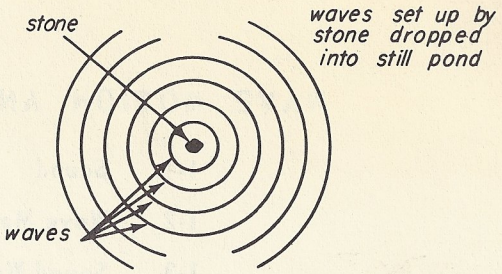


Fig. 1-1

1-3. SOUND WAVES

Like waves in a pond, sound waves in air radiate (go out) in all directions from the source of the sound. But we cannot see these waves; we can only hear them. A sound may be produced by a tuning fork, as shown in Fig. 1-3. The rapid to-and-fro movement, or vibration, of the tuning fork first presses the surrounding air into a small space, causing *compression*, and then spreads it over a large space, causing *rarefaction*. This alternate compression and rarefaction of the surrounding air is repeated, over and over again, until the vibration stops. This

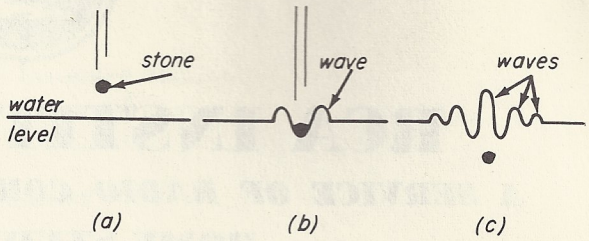


Fig. 1-2

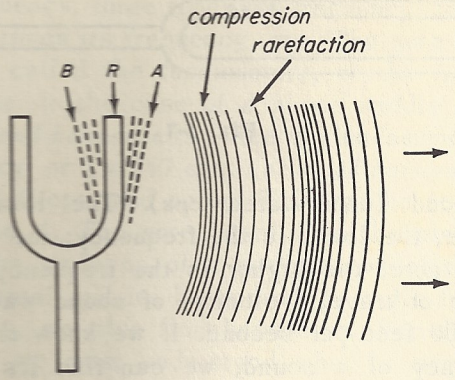


Fig. 1-3

is very important, so let's break it down and see exactly what happens. First of all, the picture shows only one prong of the tuning fork vibrating. Actually, both prongs vibrate, but, to simplify the picture, only one of them is shown in motion and the air to the right of *R* is considered. The letter *R* shows the prong at rest – when it is not vibrating. When the fork is struck, the prong moves from *R* to *A*. When it does this, it pushes nearby particles of air closer together; that is, it *compresses* the air. Maximum compression results at *A*. Then the prong starts moving back. It passes through the position of rest *R* and continues on to *B*. As this happens, the particles of air are spread. That is, the particles of air become more *rare*. At *B* maximum rarefaction occurs. Then the prong changes direction again and moves from *B* to *A*, passing through *R* on the way. Note that the air is compressed when the prong moves from *R* to *A* and back to *R*, and that the air is rarefied when the prong moves from *R* to *B* and back to *R*. This back-and-forth movement is

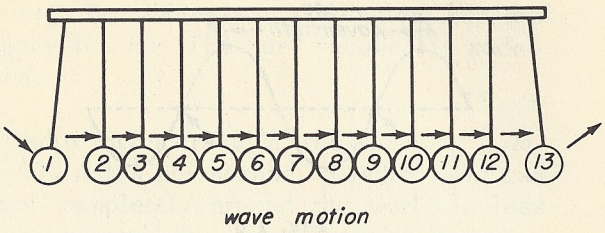


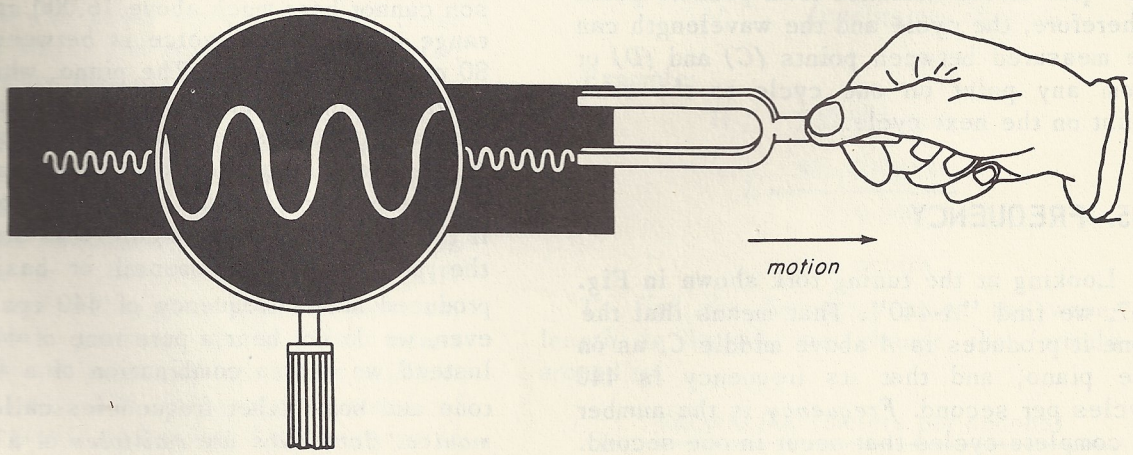
Fig. 1-4

repeated over and over until the fork stops vibrating.

The changing motion of the air set up by the tuning fork travels out in all directions from the source of sound in the same way that waves spread in water. This does not mean that the air next to the tuning fork actually travels to the ear of the listener. Instead, the motion or energy is passed from one particle of air to the next and finally reaches the listening ear. The action is much the same as that shown in Fig. 1-4. When ball #1 is moved in the direction shown, it passes this motion on to ball #2. Ball #2 passes it on to #3, #3 to #4, and so on, until it reaches ball #13. The balls in the middle of the string remain where they were; only the movement travels away from the source until it reaches the last ball.

1-4 WAVELENGTH AND CYCLE

If a prong of a vibrating tuning fork is pulled in a straight line across a smoked-glass plate, it will leave a wavy trail like that shown in Fig. 1-5. This wavy trail looks



vibrating tuning fork drawn across smoked glass surface

Fig. 1-5

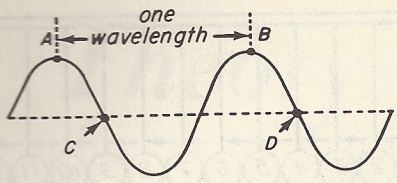


Fig. 1-6

like the waves formed by a falling stone in a still pond. This waveform appears again and again in this course, so let's take a closer look at it in Fig. 1-6. The broken line represents the trail that would have been drawn if the tuning fork had not been vibrating, but had been in the *at rest* position, like the *R* position in Fig. 1-3. The wavy line shows the amount of movement made by the vibrating prong, first in one direction, then the other; in other words, the wavy line is a graph of a sound wave. The straight line distance between the peak *(A)* on the wavy line and the next peak *(B)* is called the wavelength. (If we were to measure a wavelength in water, we would measure the length of a straight line drawn between the highest point of one wave and the highest point of the next one.) The actual path of the wavy trail from *(A)* to *(B)* is called a *cycle*. (In water, we would trace a cycle by starting at the top of a wave and moving along the surface of the water, down into the trough between waves, and up to the top of the next wave.)

Both wavelengths and cycles may be marked off from points other than the peaks of waves. However, remember that the distance being marked off on the waveform must be equal to the distance from peak to peak. Therefore, the cycle and the wavelength can be measured between points *(C)* and *(D)* or from any point on one cycle to the same point on the next cycle.

1-5. FREQUENCY

Looking at the tuning fork shown in Fig. 1-7, we find "A-440". That means that the tone it produces is *A* above middle *C*, as on the piano, and that its frequency is 440 cycles per second. *Frequency* is the number of complete cycles that occur in one second. The frequency of middle *C* is 262 cycles per

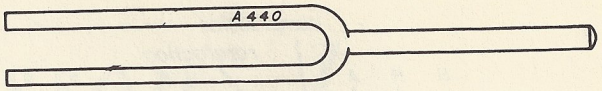


Fig. 1-7

second (abbreviated *cps*). The lower the note, the lower is the frequency; the higher the note, the higher is the frequency. The rate of travel (velocity) of sound waves is 1,100 feet per second. If we know the frequency of a sound, we can find its wavelength. For instance, the frequency of *A* above middle *C*, as we know, is 440 cps. (The tuning fork will go through one cycle in 1/440 second.) The wavelength can be found by dividing the velocity by the frequency. That will give us the wavelength in feet.

Example:

$$\text{Wavelength} = \frac{\text{Velocity}}{\text{Frequency}}$$

$$= \frac{1{,}100}{440}$$

$$= 2.5 \text{ feet}$$

1-6. AUDIO FREQUENCIES

Audio frequencies (frequencies we can hear) may be as low as about 20 cps and as high as about 20,000 cps. The average person cannot hear much above 16,000 cps. The range of the human voice is between about 80 cps and 1,200 cps. The piano, which has a wider range than most instruments, goes from about 30 cps to about 4,000 cps in its *fundamental* frequencies. *Fundamental*, as it is used here, means *basic*. For example, if the key for *A* above middle *C* is struck on the piano, the fundamental or basic note produced has a frequency of 440 cps. However, we do not hear a pure tone of 440 cps. Instead we hear a combination of a 440-cps tone and some other frequencies called *harmonics*. *Harmonics are multiples* of a tone — that is, they are one time its frequency, twice

its frequency, three times its frequency, four or five times its frequency, etc. The note itself is called the fundamental, or the *first harmonic*. In the case of *A* above middle *C*, the *second harmonic* is twice the fundamental frequency, or 2 x 440 cps. The *third harmonic* is 3 x 440 cps, and so on. This can be seen in Table *A*. The note heard from the piano would be made up of a combination of the fundamental and its harmonics. In radio frequencies, we also find harmonics. For that reason, we must understand what is meant by the term.

TABLE A

First harmonic (fundamental)	440 cps (1 x 440)
Second harmonic	880 cps (2 x 440)
Third harmonic	1,320 cps (3 x 440)
Fourth harmonic	1,760 cps (4 x 440)
Fifth harmonic	2,200 cps (5 x 440)
Etc.	

1-7. RADIO FREQUENCIES

Audio waves by themselves can travel only for limited distances. However, we can use radio and telephone equipment to carry audio waves over great distances. When radio equipment is used, audio waves can be sent all over the earth and they can be heard by millions of people at the same time. Radio transmitters send out electrical waves that carry the audio waves. We call these electrical waves the *radio-frequency carrier;* we abbreviate this phrase as r-f carrier. The r-f carrier waves have wavelength, velocity, and frequency, just as do sound waves, but they are very much higher in frequency than sound waves. The standard broadcast band of assigned frequencies starts at 535,000 cps and ends at 1,620,000 cps. To simplify speaking and writing about these frequencies, we use two prefixes: *kilo*, which means *thousand*, and *mega*, which means *million*. We then say 535 *kilocycles* instead of 535,000 cycles, and either 1.62 *megacycles* or 1,620 *kilocycles* instead of 1,620,000 cycles. We abbreviate kilocycles *kc*, and megacycles *mc*. The "per second" is understood.

Radio waves travel at the speed of light: 186,000 miles per second. A radio wave can travel completely around the world in less than a seventh of a second. If the frequency of a radio wave is known, we can find the wavelength with the same formula we used for finding the wavelength of an audio frequency:

$$\text{Wavelength} = \frac{\text{Velocity}}{\text{Frequency}}$$

Customarily, we measure wavelengths of radio waves in meters, but other units may be used (miles, feet, etc.). So, we must change 186,000 miles into meters before we can use the formula. We know that there are 5,280 feet in a mile, 12 inches in a foot, and 39.37 inches in a meter. So we find meters per second as follows:

$$\text{186,000 miles per second} = \frac{186{,}000 \times 5{,}280 \times 12}{39.37}$$

$$= \text{300,000,000 meters per second (approx.)}$$

The symbol for wavelength is λ (Lambda), which is the Greek letter *L*, and the symbol for frequency is *f*. The formula for wavelength then becomes:

$$\lambda = \frac{\text{300,000,000 (meters per second)}}{f \quad \text{(cycles per second)}}$$

Example:

If f = 500,000 cps:

$$\lambda = \frac{300{,}000{,}000}{500{,}000}$$

$$= 600 \text{ meters}$$

To find the frequency when the wavelength is known, we change the formula around to:

$$f = \frac{\text{300,000,000 (meters per second)}}{\lambda \quad \text{(wavelength in meters)}}$$

Example:

$$\text{If } \lambda = 200 \text{ meters:}$$

$$f = \frac{300,000,000}{200}$$

$$= 1,500,000 \text{ cps or } 1500 \text{ kc or } 1.5 \text{ mc}$$

If you want a simple way to remember the formulas above, try using the circle in Fig. 1-8*a*. To use it, just place your finger over the quantity you want to find, and what remains uncovered shows what you must do to find the answer.

1-8. THE RADIO COMMUNICATION SYSTEM

People who listen to radio programs may be in houses, restaurants, clubs, automobiles, or at the beach, many miles from the broadcasting studios that send out the programs. How the music, story, or news gets from the studio to the listener may be told very simply. *Why* it happens the way it does is something that you must learn. In this lesson you are getting a start toward that knowledge.

Here is a simple explanation of the way one note, *A* above middle *C*, travels from a broadcasting station to the home of a listener. Refer to Fig. 1-9 while you read this explanation.

Figure 1-9 is a block diagram of the route taken by the audio-frequency signal from the microphone to the listener's loudspeaker. It is called a block diagram because it is made up of blocks, each of which represents a large section of the broadcasting

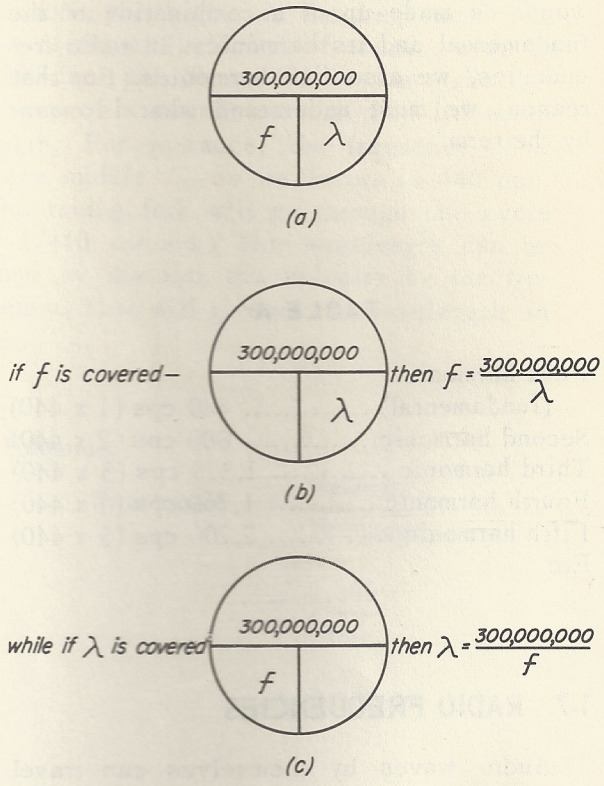
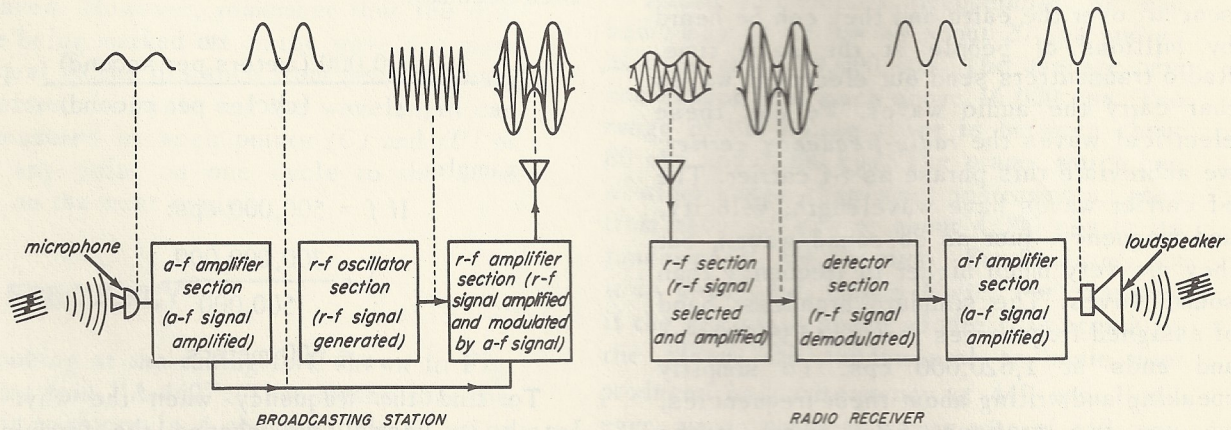


Fig. 1-8



radio broadcasting system from microphone to loudspeaker

Fig. 1-9

system. Block diagrams are easy to follow because they do not show a lot of confusing apparatus. Notice that *audio frequency* is abbreviated *a-f*, and *radio-frequency* is abbreviated *r-f*.

In Studio A of Station WXXX, one of the musicians of a world-famous orchestra sounds his *A* so that the orchestra can tune up before the concert. As servicemen, we would, of course, refer to *A* as a 440-cycle audio-frequency signal. This wave travelling at the speed of sound in air is picked up by a microphone (where it is changed to electrical energy that travels almost as fast as light). This small amount of electrical energy is carried by wire to a glassed-in booth next to the studio. In the *monitor room*, as the booth is called, an engineer sees that the 440-cycle signal is fed into an *audio-amplifier section*. An audio amplifier is a device used to increase the power of weak audio frequencies, because the very small amount of electrical energy produced when the microphone picks up the audio signal must be increased in power so it can be sent out over the air. On the block diagram, you can see that a small amount of electrical energy goes from the microphone to the audio amplifier. However, it is much greater when it leaves the amplifier on the next stage of its journey. This can be seen by the waveforms above the blocks, which show in a general way the shape and strength of the signal at different points. When the peaks of the waves are higher, the signal is stronger.

The second block in the diagram, the r-f *oscillator section*, represents the device that produces the radio-frequency energy. This energy has no connection with the audio energy at this point. It is produced independently by the r-f oscillator section. This frequency cannot be heard, but it is very powerful. It is called the *carrier frequency*, since, because of it, the 440-cycle note is able to travel to the listener's home. It is the frequency assigned to Station WXXX by the Federal Communications Commission. Each broadcasting station is given a certain frequency to operate on, so that its programs will not interfere with other stations broadcasting at the same time. Station WRCA, in New York, operates on 660 kc; WBBM, in Chicago, operates on 780 kc; KFI, in Los Angeles, on 640 kc; and WFAA, in Dallas, on 820 kc. This system makes it possible to choose the station we want to listen to.

The third block in the diagram is labelled *r-f amplifier* section. In this section, the *r-f carrier wave* is amplified. It is also mixed with the audio-frequency signal in this section. This mixing is called *modulation*. The modulated signal (the mixture of the audio frequency and the carrier frequency) then goes to WXXX's antenna, and travels out into space.

The listener, in his home, is tuned to WXXX's frequency. A small portion of the energy broadcast by the radio station is picked up on the listener's antenna, and from there it travels to his radio receiver. The block diagram shows that it enters the *radio-frequency section*. It can enter this stage because the receiver is tuned to its frequency. The weak r-f signal is amplified in this section, so that it is much stronger when it leaves. Then it travels to the *detector section*, where the radio frequency is *demodulated*, or *detected*. This means that the audio frequency is separated from the radio-frequency carrier. This process is called *detection*. After this takes place, only the 440-cycle audio frequency is left. It is still too weak to be heard over the loudspeaker, so it travels through an *audio-frequency amplifier* section to be built up. Leaving the amplifier, it goes to the loudspeaker and causes the speaker to vibrate at the rate of 440 cps. As a result, the listener hears the musical tone *A* above middle *C*.

1-9. NEED FOR BASIC ELECTRICAL KNOWLEDGE

The explanation you just read of the broadcasting system is very simple. It does not explain the *how* and the *why* of the radio apparatus mentioned. To understand a full explanation of radio systems, you must have

a complete knowledge of the principles of electricity and electronics. No one would try to build a skyscraper like the Empire State Building, a bridge like the Golden Gate Bridge, or a dam like Hoover Dam without first learning all he could about bricks, stone, cement, structural steel, cables, and so on. Just as a builder would have to know about these things, so a serviceman has to know about resistors, capacitors, inductors, and electron tubes before he can understand radio and television.

In the lessons that follow, you will learn something about electricity and electron tubes. You must do this before you can understand how and why radio and TV circuits work. With the knowledge obtained in these early lessons, you will be able to study and work with radio and TV circuits. However, this knowledge won't be yours unless you try, and keep on trying, to learn everything that will contribute to a better understanding of basic theory. In the beginning, you may find that it takes a lot of effort to master the basic principles. However, when you do master them, you'll find the later lessons much easier to understand. Remember – a thorough knowledge of radio and TV is very valuable. It is worth all the effort you put into it.